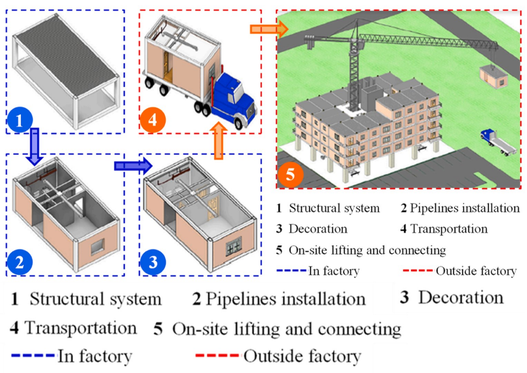
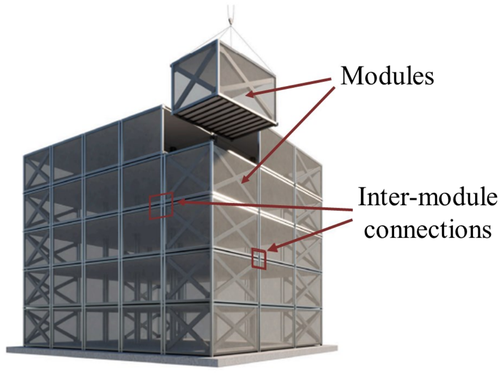
# Development of earthquake resistant guidelines for inter-module connections of modular buildings

## • Introduction

**Background:** Modular building is a kind of prefabrication construction. By connecting individual modules manufactured in the factory into a whole structure, modular buildings have better efficiency, higher quality control, the potential for lower cost, and sustainability benefits. In modular buildings, loads and deformation mainly transfer through inter-module connections. Therefore, inter-module connections are important for modular buildings in resisting gravity and lateral loadings and play a significant role in the design of modular buildings.




Construction of modular building [1]



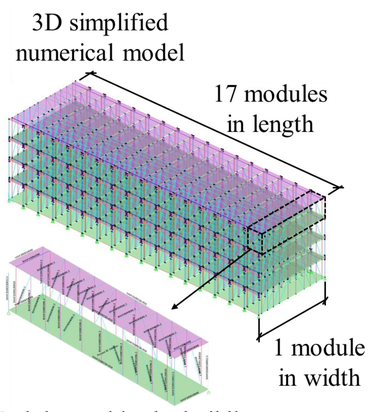

Modular steel building [2]

**Aims and objectives:** This project used an existing modular steel building as the prototype model, proposed to investigate the effect of the properties of the inter-module connections on the behaviour of modular buildings, analyse the seismic performance of modular buildings. Based on the results, this project aimed to assess the structural behaviour of modular buildings, develop a design guideline for inter-module connections of modular buildings, and provide some suggestions for future research.

## • Computer simulations

**Prototype model:**

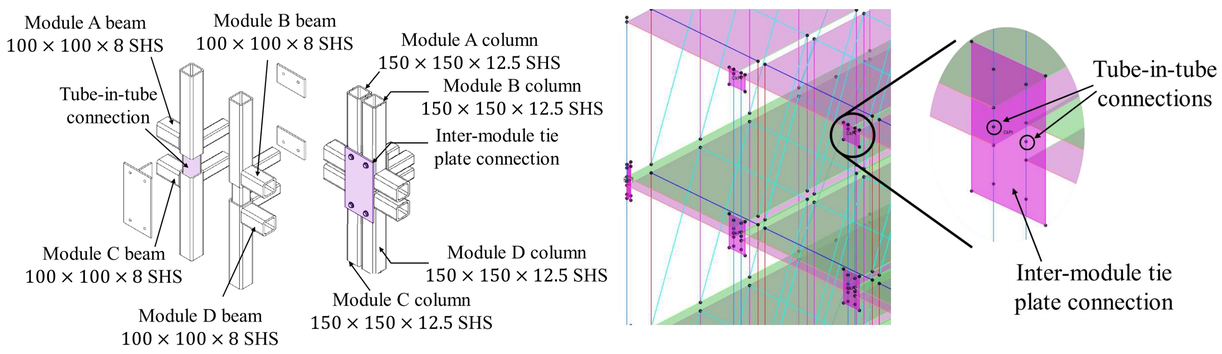
The prototype model is based on an existing modular building, which is a one-block building, four stories high, with seventeen modules in length and one number of units in width. The three-dimensional (3D) simplified numerical model was established using a commercially available software.




Module used in the building

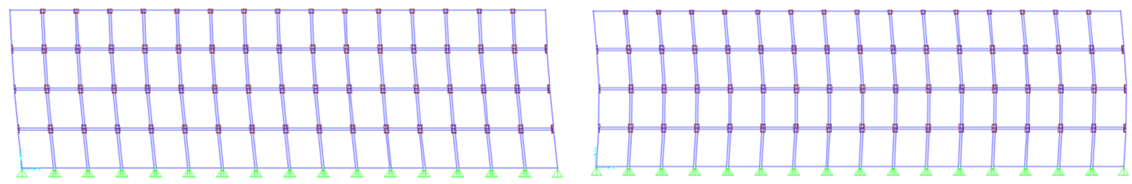
**Inter-module connections:**

The vertical connection between two modules utilises a tube-in-tube connection. In the numerical model, the vertical connections were modelled as pin connections. By defining the inter-module tie plate connections with steel plate in the software, the thick-shell element was used, which allows identification of the location of maximum forces stress contours and the initiation of the plastic strain. The connections between the tie plate connections and the steel frame were defined by assigning an automatic area mesh with designated nodes corresponding to bolt locations.




## • Results and discussion

**Linear dynamic analysis:**



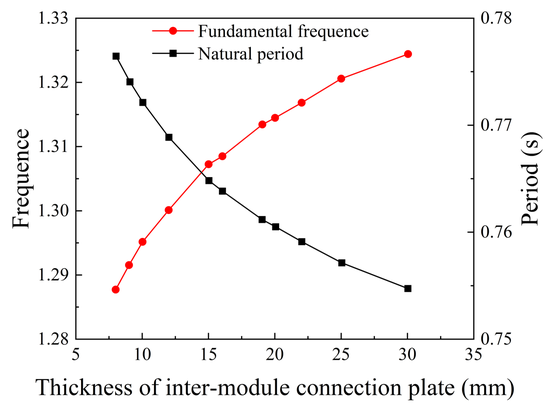
1st Mode
f=1.257Hz, T=0.795s

2nd Mode
f=2.538Hz, T=0.394s

■ The dynamic structural behaviour of the modular building conformed to a typical single-degree-of-freedom cantilever structure.

■ The first two modes occupied most of the modal mass partition ratio.

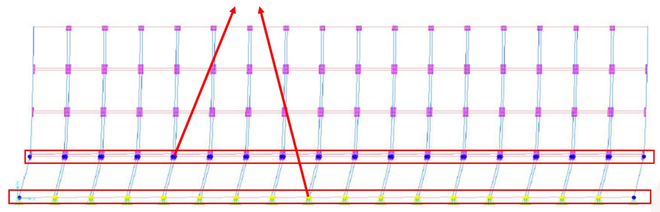
■ The increase of the thickness of the inter-module connection plates can lead to a decrease in the natural period.




**Nonlinear static analysis:**

■ In the nonlinear static analysis, the plastic hinges first occurred in the ceiling beam-column connections and the floor beam-column connections of the bottom floor modules.

The plastic hinges first occurred in the beam-column connections of the bottom floor modules



## • Conclusions and future work

**Conclusions:**

[1] The dynamic structural behaviour of the modular building conformed to a typical single-degree-of-freedom cantilever structure. The first two modes occupied most of the modal mass partition ratio.

[2] The increase of the thickness of the inter-module connection plates can lead to a decrease in the natural period.

[3] In the nonlinear pushover analysis, the plastic hinges in the modular building first formed at the beam-column connections of the bottom level modules.

**Future work:**

[1] Parametric studies can be taken to further investigate the effect of different parameters such as building height and number of modules on the dynamic properties of modular buildings.

[2] For modular buildings under seismic load, inter-module connections can be allowed to have some deformation instead of completely rigid to reduce the seismic response of the building. Therefore, for the design of modular buildings, inter-module connections can also be categorised as part of the dissipative regions to minimise the damage under seismic action.


## • Acknowledgement

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## • References


[1] Liew, J.Y.R., Chua, Y.S. and Dai, Z. (2019). “Steel concrete composite systems for modular construction of high-rise buildings”, Structures, 21, 135-149.

[2] Farajian, M., Sharafi, P., Eslamnia, H., Bai, Y. and Samali, B. (2023). “Classification system for inter-modular connections in non-sway corner-supported steel modular buildings”, Structures, 49, 807-825.